



Western Cape
Government



Green Cape 2040: Towards a smarter grid FuturesCape Policy Research Paper

A policy research paper produced by the Department of the Premier's Chief Directorate: Policy and Strategy as part of the FuturesCape Project in collaboration with:



This policy brief is the third¹ in a series produced by the Western Cape Government's FuturesCape Project – in collaboration with the Institute for Security Studies and the Frederick S. Pardee Center for International Futures at the University of Denver – to analyse trends and comparative policy options around the six transitions of the One Cape 2040². This policy brief focuses on the Green Cape transition of the One Cape 2040 document with a focus on residential Solar PV (photovoltaic) uptake and the potential effects on municipal revenues. **While this brief explores policy options it does not constitute official policy of the Western Cape Government.**

Executive Summary

Electricity is crucial for the economic and social development of South Africa, but disruptive changes loom on the horizon. It is now clear that Eskom is unlikely to keep its electricity prices lower than those of alternative forms of electricity production, most notably small-scale photovoltaic. As the current structure of municipal revenue provision relies heavily on electricity consumption for funding, an increase in residential production of PV could be disruptive.

Small-scale solar PV systems have become cost effective for many higher-income private consumers, who are paying the highest tariff margins on their electricity. As these costs continue to fall, it will become an increasingly affordable option for many more households. There is significant uncertainty about how a potential shift to decentralised PV will affect the ability of municipalities to continue pro-poor social spending.

This analysis finds that a significant amount of revenue will be lost to PV uptake, but that policies aimed at investing in advanced metering infrastructure (AMI) and other smart technologies, changing the tariff structure and encouraging economic growth from domestic PV manufacturing can reduce this loss. Because many of these technologies have not yet reached maturity and there is uncertainty over how smart grids will be deployed, this analysis suggests that policies be pursued sequentially. First, over the short term, the province should promote the use of AMI to provide policymakers and planners with the data they need to make effective decisions about private PV. Second, in the medium term, the province should consider investing in limited smart grid technology – a system where decentralised and centralised electricity production can coexist. Third, in the long term, the province should explore promoting the local PV industry to take advantage of this unfolding trend in renewable energy production, and look to other global cities for lessons in deploying more advanced smart grid technology.

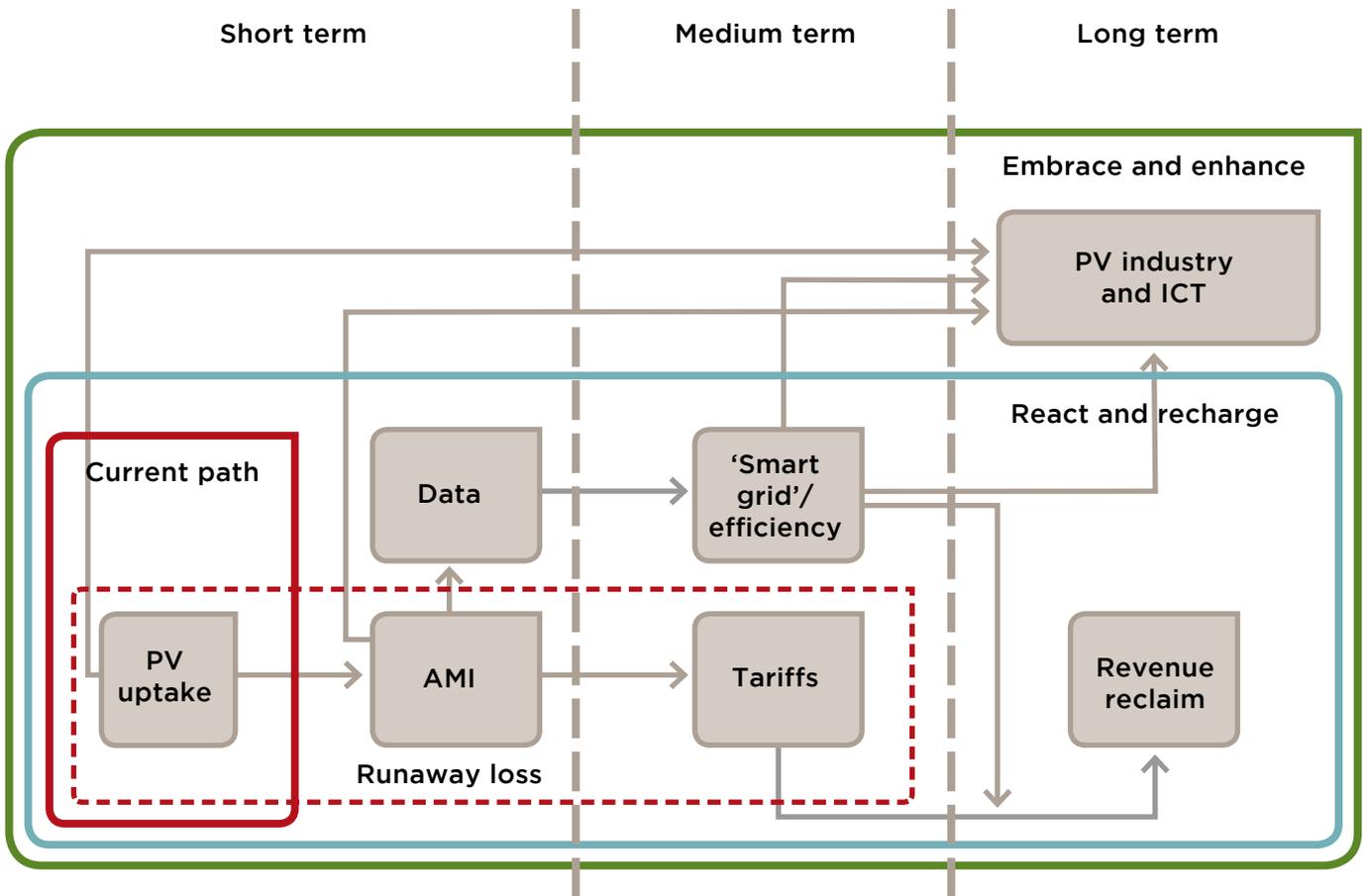
To understand some implications of these different policy options we have modelled four different scenarios using the International Futures model (IFs)³. In the **Current Path**, residential PV uptake occurs without any long-term investment in smart grid infrastructure from Western Cape municipalities or the Western Cape Government.

React and Recharge accompanies residential PV uptake with the implementation of tariffs that allow the purchase of electricity from residential consumers (feed-in tariff, or FIT) as well as investments in AMI. The data gathered from AMI is used to inform decisions on the efficiency of the grid, mitigating revenue loss. To illustrate the importance of institutionalising the use of AMI data to inform grid decision-making, a negative alternative scenario to React and Recharge is presented, called **Runaway Loss**. Runaway Loss includes feed-in tariffs and investments in AMI. However, Runaway Loss is modelled without the improvements in grid efficiency and effective administration of feed-in tariffs seen in React and Recharge, leading to even more revenue losses than in the Current Path.

In **Embrace and Enhance**, PV uptake is met with high levels of investment in AMI, smart technologies and the local PV industry itself, which leads to even more revenue reclaimed through tariffs than in React and Recharge as well as spillover economic gains in the PV industry and through the spread of information and communications technology (ICT).

Figure 1 frames each of the key variables modelled in the scenarios described above.

Figure 1: Possible paths to revenue reclaim over three time horizons



Note: Each coloured rectangle corresponds to a scenario. The Current Path is a future without AMI – policy does not change and revenues are lost. Runaway Loss has investments in AMI and implementation of tariffs that further encourage PV uptake without considering longer-term implications. React and Recharge matches investments in AMI with data-informed investments in efficiency so that tariffs are translated into reclaimed revenues. Embrace and Enhance contains all of the benefits of React and Recharge with the added spillovers in the PV industry and ICT sectors.

Source: Authors' conceptualization.

The authors recommend that the province promote the use of AMI over the short term. AMI will enable the use of tariffs while providing the data necessary to make informed decisions regarding investments in residential PV and smart technologies in the medium term. Depending on this data, the province could choose to pursue an Embrace and Enhance future, further mitigating revenue losses (though not fully offsetting them). Investments in smart infrastructure have uncertain and long-term payoffs, however, and should be seen as strategic possibilities rather than current policy goals.

These policies alone will not solve the municipal revenue problem – in all of our scenarios the province experiences significant revenue losses. However, decisions made now using the foresight available in this brief can keep the province ahead of the curve. Private PV uptake is inevitable and the province can either fight the trend and possibly experience increasing revenue losses or embrace clean energy and smart technology and promote a 'Green Cape'.

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Key concepts

Capacity vs. output

Capacity refers to the amount of power a particular system can generate, while output refers to the amount of energy it produces over a time period. Because renewable power sources are often variable, output from two systems with the same capacity can vary depending on conditions.

Installed costs vs. levelised cost of electricity

Installed costs are the up-front capital investment of installing an energy generation system, before it has begun producing power. The levelised cost of energy (LCOE) refers to the average cost of producing a unit of energy over the lifetime of that system, taking into account not just installed costs but also the cost of fuel, taxes, maintenance, etc.

Peak demand

This refers to the period in which the highest amount of power is used collectively by all consumers within a particular energy environment, such as a city or province. Peak demand in the Western Cape typically occurs on weekdays between 07h00 and 10h00, and again between 18h00 and 20h00.

Power vs. energy

While commonly used interchangeably, technically electrical power and electrical energy are distinct. Energy is a measure of how much fuel is consumed by something over a period of time, while power is a measure of the rate at which the energy is being generated. Power is commonly measured in watts (W), kilowatts (kW), megawatts (MW) and gigawatts (GW), while energy is measured in kilowatt hours (kWh) or gigawatt hours (GWh). As an example, a 100 W light bulb turned on for 10 hours consumes 1 kWh of electricity, but a 1 kW appliance run for 1 hour also consumes 1 kWh of electricity. The power required to run each appliance is different, but their energy consumption can be the same depending on the length of use.

The Western Cape's electricity dilemma

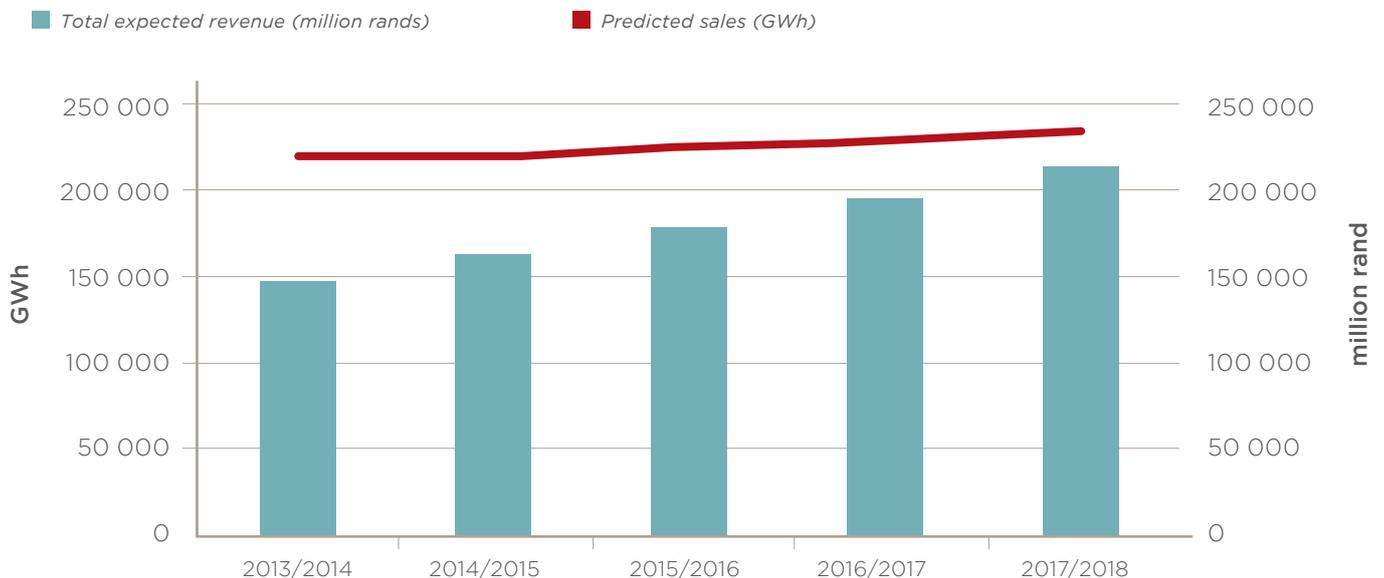
Situational analysis

Electrification campaigns in South Africa have been one of the great successes of the post-apartheid era, bringing power to some of the poorest communities.⁴ Yet in recent years, while the population and incomes have increased, electricity supply growth has stagnated. According to Statistics South Africa, total electricity available for distribution peaked in 2011 and has since slightly declined to 233 105 GWh in 2013, with production in 2014 only barely keeping pace.⁵ Meanwhile South Africa's Integrated Resource Plan (IRP) 2010-2030 projects that demand for electricity is likely to reach approximately 345 000-416 000 GWh by 2030.⁶ This means South Africa will need to increase production by almost 50% above 2013 levels to meet even the low boundary of demand in 2030.

The pressures on Eskom⁷ suggest achieving the target will be difficult. The costs of financing significant new generation capacity while maintaining current infrastructure resulted in large increases in tariffs in 2010-2012. The National Energy Regulator of South Africa (NERSA) approved an increase of 8% a year from 2013 to 2018, and then approved additional increases in August 2014. As shown in Figure 2, Eskom expects these measures will rapidly increase the amount of revenue it can extract from a similar level of sales, improving its financial stability.

These measures are arguably a long-overdue attempt to better match the price of electricity to the cost of supplying it, as electricity prices prior to 2008 had declined for decades despite rising costs of generation.⁸ Where in the 1990s the price of electricity in South Africa was among the cheapest in the world at R0,25/kWh (Eskom selling price),⁹ as of October 2014 the Eskom selling price stood at R0,65/kWh,¹⁰ moving closer to the global average.¹¹ It is not yet clear what the total percentage increase will be over the next five years on top of the current price, although Eskom is attempting to keep it to 12% a year.¹²

Figure 2: Projected Eskom sales vs. revenue, 2013-2018 (with 8% a year increases)



Note: Official projections of Eskom electricity sales and revenue over the next five years, taking into account an 8% annual price increase. Ultimate price increases for 2013-2018 are now expected to be higher than 8%.

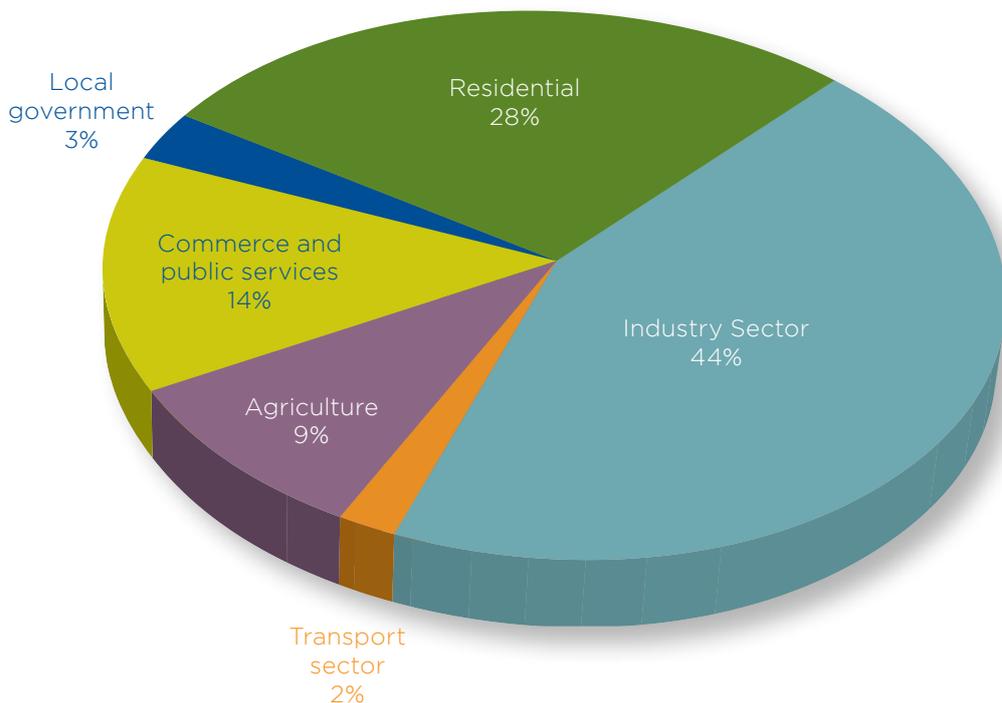
Source: National Energy Regulator of South Africa (NERSA), Multi-year price determination 2013/2014 to 2017/2018, (2013).

Yet despite the revenue increases, Eskom has been losing capacity to equipment failure at a faster rate than it builds new capacity. In an editorial piece, University of Cape Town (UCT) energy expert Professor Anton Eberhard wrote bluntly that, ‘we now know Eskom cannot supply all our power needs’.¹³ Even if Eskom realises the revenues it projects, an inability to efficiently and reliably deliver electricity will result in continued load shedding and blackouts.

Grid electricity consumption among Western Cape residential and commercial users has declined since 2009, while consumption in other sectors has grown.¹⁴ Much of the decline is likely a result of efficiency measures, including the rollout of solar water geysers across much of the province. While reduced Western Cape demand helps alleviate some of Eskom’s supply problems in the short term, it does not solve them. This decrease in demand is unlikely to continue alongside growing gross domestic product (GDP), and it is uncertain whether other provinces are experiencing a similar trend. The most recent update to the IRP lowered its projected demand for South Africa in 2030 from the originally published figures, but still found there would be a substantial need for more capacity. Further, while decreased consumption could benefit Eskom in the short term, in the long term it could harm its ability to invest in capacity, since it reduces the possibility of realising the revenue increases projected in Figure 2.

The environmental impact of electricity production in South Africa is also troubling. Over 90% is generated by burning fossil fuels, and the majority of that production is from coal, a carbon-intensive fossil fuel. The World Resources Institute found that in 2012 South Africa was the 18th largest country emitter of atmospheric carbon dioxide in the world and the 13th largest emitter per capita, despite being only the 29th largest economy.^{15,16} As a result, Western Cape industries such as agriculture could suffer from carbon taxes, which disadvantage their products relative to those of international competitors.¹⁷

Figure 3: Western Cape electricity consumption by sector, 2012/2013



Source: Western Cape Department of Environmental Affairs and Development Planning, Provincial Energy Balance 2009 vs. 2012/2013, (2014).

The Western Cape hosts the Koeberg nuclear power plant and a limited number of renewable generating stations, including operational wind farms at Klipheuwel and Darling.¹⁸ However, Western Cape energy demand is largely met with coal-fired electricity from the national grid. Rising prices and unreliable delivery will put increasing pressure on Western Cape residents in coming years. But where once consumers had little choice but to either pay their tariffs or rely on expensive independent diesel generators, global shifts in the price of technology mean that other options are increasingly becoming cost effective.

The rise of residential and commercial solar PV

The rapid growth of the global solar energy market has been one of the most promising developments in renewable technology. Once too expensive for all but the most remote private consumers, global costs of PV have fallen at a steady and rapid pace. A 2012 analysis by the International Renewable Energy Agency (IRENA) found that total PV module costs declined nearly 20% in 2010–2011. It forecasts that by 2015 the cost will have declined to less than half the price of 2010 (from US\$1,75/W to US\$0,85/W). The average global levelised cost of electricity (LCOE)¹⁹ for solar PV in 2012 was estimated to be increasingly competitive with averages for fossil fuel-generated electricity.²⁰ Today PV systems can be purchased in the retail market and installed in just a few days.^{21,22} Combined with increasing market maturity and governments' focus on stimulating renewable energy sources, PV experienced the most rapid growth rates in energy technology in the world since 2000. From 2010 to 2013, global cumulative installed PV capacity grew by 244%.^{23,24}

Recognising the potential for renewable power, the IRP introduced the national Renewable Energy Independent Power Producers Programme (REIPPP), an initiative opening up five bidding windows for independent competitive bids to install 3 725 MW of renewable energy. Of this total, 1 450 MW in open bids was allocated to PV technology.²⁶ Between Bid Window 1 and Bid Window 2 of the REIPPP, the price of generating one MWh dropped from R2 758 to R1 645, which was in part attributed to the decline in the price of PV modules.²⁷

When the 2013 update to the IRP was released, it took note of a related PV trend: small-scale home solar generation. The authors write that 'it has become highly probable that electricity consumers ... will begin installing small-scale (predominantly roof-top) distributed generation to meet some or all of their electricity requirements'.²⁸ In contrast to REIPPP production, which is large scale and directly fed to Eskom, residential solar production is fed directly to the house or building on which the PV system is installed.

Installing residential PV usually does not mean that a homeowner no longer uses grid electricity. Most PV systems are not installed with significant battery storage, and because the system can only produce energy during daylight hours it is generally not sufficient to supply all the needs of a particular household or building. When the PV system is not producing or not producing enough to meet the owner's requirements, the grid usually makes up the balance. There may also be times during the day when PV production is more than required, and this excess electricity is usually lost. However, the global cost of battery storage is also declining, raising prospects for 'grid defection' by residential consumers.²⁹

While residential solar could bring a variety of benefits to the South African energy mix, including high-tech skills development and emission reductions, the financial situation of municipalities as electricity middlemen is a serious complication. Roughly 60% of South African customers buy electricity from their local municipalities, who have in turn bought in bulk from Eskom.³⁰ Income from those sales is a key source of funding for municipalities, who often rely on the high margins paid by richer residents to fund maintenance costs and subsidise municipal services for poorer residents.³¹ With grid tariffs rising and the costs of PV systems falling, these crucial consumers are likely to be the first to have both the means and incentive to invest in residential rooftop PV systems, whether such systems are legal in their local municipalities or not. Several municipalities in South Africa already allow legal residential rooftop PV connections, including Cape Town, Johannesburg, Ethekewini and Ekurhuleni.

Responding to the trend of high-tariff consumers in Cape Town reducing their water and electricity bills through conservation, Executive Deputy Mayor Ian Nielson stated that it was less likely that the council would be able to provide as many free and subsidised services in future.³² Energy analyst Dirk de Vos found the potential of residential solar troubling, writing in the Daily Maverick: 'Electricity could well go the way of health and education, where the top end of the market privatises and secures its own quality supply while the bottom end has to make do with what the state can provide.'³³

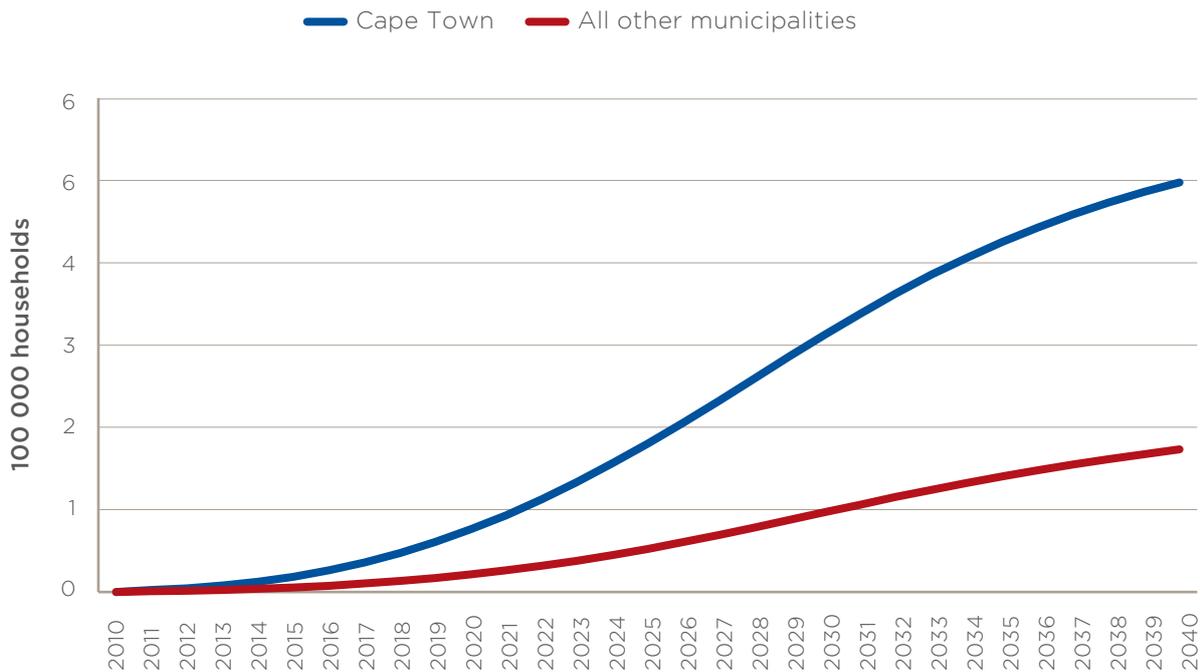
Potential futures of solar PV in the Western Cape

Current path: the municipal revenue crunch

A handful of detailed studies attempt to estimate the revenues each municipality might stand to lose if PV uptake proceeds. A profile of Cape Town suggested that within 10 years 2% of total revenue (and nearly 10% of operating revenue) could be lost if 100 000 customers install rooftop PV systems.³⁴ Another report on Cape Town estimated that between 15–25% of the Electricity Services Department’s operating expenses (a different metric than overall operating revenue) could be lost.³⁵ Elsewhere, a study of Witzenberg found a similar level of impact on revenue as that estimated for Cape Town,³⁶ but a study of Riversdale in the Hessequa local municipality concluded that there was relatively small capacity for PV uptake, and therefore there would be almost no impact on municipal operating revenue.³⁷

We have constructed our own model to forecast residential PV uptake and the corresponding revenue losses out to 2040. Our Current Path scenario is a future where residential PV increases in a context of current tariff trends and little substantive change in municipal policies towards PV. This scenario is compared to a Base Case in which no significant residential PV installation occurs.³⁸

Figure 4: Forecasted uptake of PV for the Cape Town Metro versus all other municipalities



Source: Authors’ forecast. See Appendix B for description of model.

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We separated the Cape Town Metro from the remaining municipalities and made separate assumptions and forecasts for each. Cape Town was assumed to have a higher PV adoption rate relative to other local municipalities due to its size and position as the central hub for technology and wealth in the Western Cape. Existing studies of Cape Town also suggest that relatively robust PV uptake is likely. For the other local municipalities that lack similar economies of scale, the evidence is more conflicting, as the studies of Hessequa and Witzenberg find quite different impacts that are directed by different forecasts of PV uptake.³⁹

We use the International Futures model (IFs) to develop integrated projections of the Base Case and Current Path out to 2040 (See Appendix A for a description of the IFs model), and examine trade-offs with other potential futures.

Modelling PV uptake

Forecasts of the total number of households connected to electricity out to 2040 were drawn from IFs.⁴⁰ 'Max PV access' is defined as the total number of households that have the possibility of installing PV. This varies as the number of connections increases. This parameter is almost entirely a function of income – high-income consumers are likely to use more electricity and are charged at higher rates, and thus have greater incentives to install cheaper PV.

We estimate max PV access as a constant portion of total household connections. This parameter ranges from as high as 41% of potential households in the Cape Town Metro installing rooftop PV and as low as 31% of households in non-Cape Town local municipalities.⁴¹ This relies on assumptions regarding income and electricity tariff structure. We assume an average 11.3% growth rate of PV⁴², an average 6 kWp (kilowatt peak) PV installation, increased efficiency in PV over time, and a take-off year of 2016. For a detailed description of this model and its assumptions, see Appendix B. Under these assumptions we forecast that 671 000 households will have PV systems or an investment equivalent by 2040, equalling 31% of all household connections in the province.⁴³

We do not explicitly model or forecast commercial PV uptake in our scenarios. Commercial PV uptake could significantly increase overall revenue losses for the Western Cape, though AMI, tariffs, smart grids and ICT could also produce enhanced spill-forward effects that mitigate revenue loss. Further study of this is needed to more fully understand this issues area.

Results

We find that by 2040, residential PV is forecast to generate almost 6.7 million barrels oil equivalent of energy each year. This is equivalent to almost 11 000 gWh, roughly half of total final electricity consumption in the Western Cape in 2012/2013 and over 23% of forecasted Western Cape electricity production in 2040. To forecast revenue losses we assume that this energy would otherwise have been purchased at the 'Domestic high' blocks of electricity consumption, and that these tariffs will increase over time.⁴⁴ This results in increasing revenue losses – reaching an annual high of 23% in 2040 compared with the Base Case. Cumulatively, the Western Cape is forecast to lose almost 11% of municipal revenue to private PV in the Current Path scenario.

Revenue losses could be very different from these forecasted numbers (higher or lower). Due to the uncertainty regarding many of the assumptions in our model, we have conducted sensitivity analysis around PV uptake and revenue loss forecasts (more information can be found in Appendix B). Even in a scenario in which only about 200 000 households in the Western Cape install PV – a very low level of potential PV uptake – municipal revenue loss across the province is still a significant 6% in 2040. Despite the high degree of uncertainty regarding private PV uptake, the results suggest that over the long term a reasonable uptake of solar PV in current conditions could strain municipal budgets if current policies remain in place.

React and recharge: the tariff response to change

One way of offsetting some revenue losses is through a tariff system (FIT) that would allow the municipality to buy PV electricity from residential producers and resell it to other customers. This is a model that is being used by utilities elsewhere in the world to cope with changing legal requirements and incentives for renewable energy, most notably in Germany.⁴⁵ These tariff systems, however, depend critically on investing in modern electricity infrastructure, the first step towards creating what is popularly called a smart grid. These tariffs also work well with Time of Use (ToU) tariffs. ToU tariffs are tariff structures that fluctuate throughout the day, depending on the current demand levels of the system. By increasing the cost of electricity during peak hours, municipalities can discourage consumption, and with a FIT even encourage production.

Smart grids and AMI in global use

Global examples

Italy began its renewable energy transformation by focusing on improving national infrastructure to accommodate small-scale cogeneration of renewable electricity. Italy collaborated with private industry to leverage expertise and funding. The Italian authorities initiated the Smart Medium Voltage Networks project to allow such networks to accommodate PV of a 1 kW or 1 MW capacity. Italy also initiated a mass roll-out of 32 million smart meters to low voltage customers – this enabled the introduction of an hourly rate tariff system.

Germany introduced a net pricing law in 2009, in addition to an FIT. Once a homeowner or company invests in a roof PV system, the government pays the homeowner or company for the energy produced. The net pricing model led to rapid development of the German PV industry. Germany has surpassed Japan as the leader in the PV market in terms of being the largest and the fastest growing, owning 47% of the PV market share. There has been a resultant rapid decrease in the price of PV energy production, showing the important role of subsidy and net pricing as policy measures to increase the development of a PV energy system.

- Marilyn A Brown and Shan Zhou, 'Smart-grid policies: an international review', *Wileys Interdisciplinary Reviews: Energy and Environment*, 2:2, March/April 2013, 121-139;
- Vincenzo Giordano et al., 'Smart grids projects in Europe: lessons learned and current developments 2012 update', *European Union Joint Research Centre, Scientific and Policy Reports*, 2013, http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/ld-na-25815-en-n_final_online_version_april_15_smart_grid_projects_in_europe_-_lessons_learned_and_current_developments_-2012_update.pdf (accessed 25 November 2014).

The advantages of a smart grid over traditional grids lie in the two-way flow of information between all parts of the grid, and the embedded use of digital communications to improve its efficiency. In a traditional grid, the flow of electricity is one way – from large central producers to transmission and distribution networks, then to residential and commercial end users. It is a system focused on mass production, centralisation and capitalising on economies of scale. The system is prone to blackouts and inefficient allocation of electricity from suppliers to consumers because of poor data availability.

By contrast, a smart grid is a system that integrates advanced sensing, control methods and communications into the everyday operations of the grid in both its transmission and distribution.⁴⁶ Renewable energy is decentralised and intermittent. Production depends on the weather, private investment and demand patterns. Smart grids serve as an ideal platform to host renewable power generation, and are more attack-resistant, self-healing in response to disasters⁴⁷ and more flexible to varying generation and storage types than a traditional grid.⁴⁸ The underlying network of systems that enables the communication is referred to as AMI. AMI does many things, including increase overall efficiency, but its most basic use is to enable the collection and analysis of much more extensive data on electricity consumption than is possible in a traditional grid.⁴⁹

No country in the world has a completely smart grid. Instead, countries are slowly modernising their grids through investments in the necessary metering and regulatory infrastructure. Capital funding for smart grid projects is one of the largest initial barriers to overcome, as the payoff period is long term.⁵⁰ Other barriers cited include disorganised or inadequate government policies, opposition from distribution companies with incentives to discourage competition, and privacy and security concerns inherent in increased interactivity and information-gathering throughout the grid.⁵¹

While efficiency in the grid is an important benefit, smart grid investments could also have the effect of stimulating renewable energy production through the integration of small producers into the grid.⁵²

AMI and smart meters

Smart meters are at the centre of the move towards AMI. These meters are installed in homes or commercial buildings and record consumption at intervals throughout the day, communicating this information to the utility remotely on a regular basis. This is in contrast to standard mechanical meters, which do not digitally communicate with the utility and are either pre-paid or manually recorded each month. Smart meters give much better information to utilities about demand and provide consumers with regular, updated information on a household or business's consumption.⁵³ Such meters also enable a variety of residential tariffs beyond the current flat 'per kWh' structure. Smart meters are necessary for FITs, as traditional meters do not allow consumers to produce energy and sell it back to the grid. Likewise, ToU tariffs are reliant on fluctuating energy prices and require high-speed information to discourage consumption or encourage production (when paired with FITs). Analysis regarding the benefits of smart technology is highly dependent on the data that AMI can make available.

Forecasting recovered revenue

The IFs Base Case includes modest increases in renewable energy generation in South Africa – including wind and utility-scale solar – in line with the goals of the IRP and the REIPP. Because the IFs model is integrated, additional generation from residential and commercial solar sources will change the complex balance of energy supply, demand, prices and investment, and have long-lasting effects on the economy and human development of the Western Cape.⁵⁴ For example, the decreasing cost of residential PV will drive investments in renewable energy production, increasing the value added to the economy from the energy sector and thus increasing GDP per capita.

As previously mentioned, solar PV production is typically not well matched with residential consumption, and excess electricity goes to waste. With investments in AMI, however, tariffs can be devised to allow a municipal utility to harness this excess production. A net feed-in tariff (Net FIT) is a billing scheme in which PV owners can ‘push’ electricity back to the grid and be compensated for it through a credit on their electricity bills. This credit is usually less than the going market rate for grid electricity, but partially subsidises an owner’s PV costs. We model the effects of such a scheme on the Western Cape by decreasing the capital to output (rand/barrel oil equivalent) ratio in IFs for renewable energy at a faster rate than in the Current Path scenario, to simulate the improved cost-effectiveness of PV. To create a new scenario in which Net FIT is adopted in the province – called React and Recharge – we assume that the level of investment in AMI will mirror the levels of uptake in rooftop PV, as municipalities observe customer investment in PV and move in tandem.

We assume a current smart meter (installation costs included) to cost about R4 000. We assume that this cost will drop logarithmically to below R3 000 over the next few years.⁵⁶ This means that investment in smart meters in React and Recharge will cost over R8 billion cumulatively by 2040.⁵⁷ Some of this cost could be borne by PV owners but would raise the price of the PV system overall and prolong the payback periods for the technology.

Increased output from smart meters and Net FIT creation

If investment in smart grid infrastructure and attractive Net FIT can successfully reduce the capital to output ratio⁵⁸ of PV by 20% below the Current Path levels by 2040, the Western Cape could produce an additional 8 million barrels oil equivalent by 2040, a 32% increase in renewable energy production over the Current Path.⁵⁹

This increase in production can shift the energy mix and environmental balance significantly. Lower levels of fossil fuel consumption can reduce the carbon footprint of the Western Cape by almost 9% below Current Path levels by 2040. Further, since thermo-electric power generation is a large consumer of industrial water use, reducing the amount of non-renewable power generation will also significantly reduce overall water demand.⁶⁰

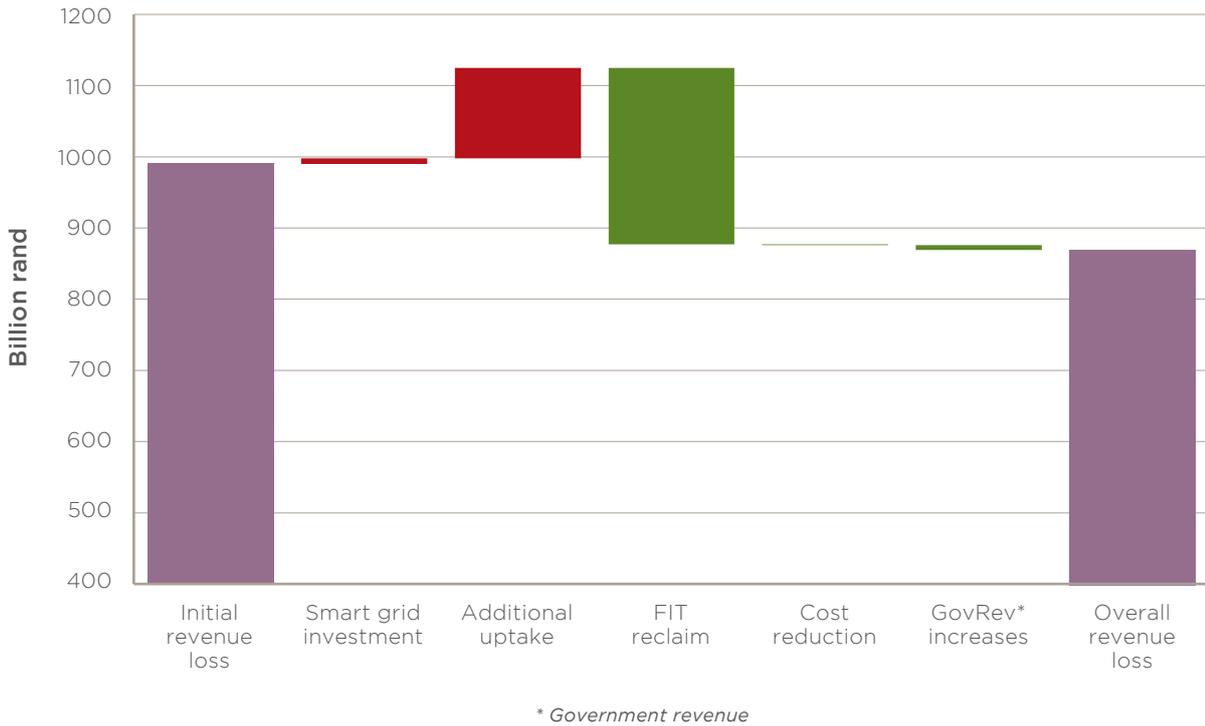
A system of AMI and rewards for feeding in electricity will also encourage increased solar PV uptake, as it becomes a more cost-effective investment for the average homeowner. This additional increase in PV production will further increase revenue losses, that is, the amount of electricity no longer being bought from the traditional grid. Using the IFs forecasting model we estimate that this additional PV uptake could add an additional R127 billion in revenue losses.⁶¹ The decreased cost of PV due to these tariffs, however, will decrease the competitiveness of other fuel types, such as coal, gas and nuclear. This will decrease investments in other energy types relative to the Current Path. We estimate a cost reduction of R885 million cumulatively from other energy sources – not very much when compared to overall revenue losses.

The amount of revenue losses that municipalities will be able to reclaim from the Net FIT will depend on the tariff imposed on the excess electricity they receive from PV owners and the degree to which the municipality can successfully redistribute this excess supply. In order to fully capitalise on AMI, a tariff structure must be set up that buys electricity from private producers for less than the resale cost and less than the Eskom bulk purchase cost. In React and Recharge, we modelled a Net FIT where the price of electricity bought from private producers is 50% of the resale price the municipalities charge on that electricity.

Reclaiming lost revenue through redistributing private production requires a smarter and more efficient grid. If the grid is not able to redistribute the energy produced by private PV effectively, the municipality can lose even more revenue than the Current Path scenario relative to the Base Case. This is a scenario where the municipality is still buying excess energy from consumers and encouraging further PV uptake without capitalising on the redistribution of the energy or the cost reductions of investments in other fuel types.

While FITs are necessary in this scenario, and ToU tariffs can complement FITs by allowing more flexibility in encouraging production and consumption, the tariffs could further increase revenue losses if there is not a grid smart enough to redistribute this excess energy efficiently. We add a parameter to this scenario that increases transmission loss of excess production of energy as the number of private PV installations increases. As private PV increases it will become more and more difficult to manage these decentralised and intermittent producers, thus further necessitating smart grid technology. However, how and where to invest in smart grid technologies will depend on the data gathered from AMI, which is why AMI is a necessary first step to realising the potential benefits of an FIT system.

Figure 5: Revenue loss and component costs and benefits in React and Recharge



Note: All figures cumulative over time horizon. Initial revenue loss of R990 billion displayed on the left followed by additional losses from investment and additional incentivized PV uptake in red. Revenue reclaim displayed in green as well as cost reduction and increased revenue from economic growth. Overall revenue loss of R870 billion displayed in purple on the right. Note that the y-axis starts at R400 billion. All data in 2011 rand.

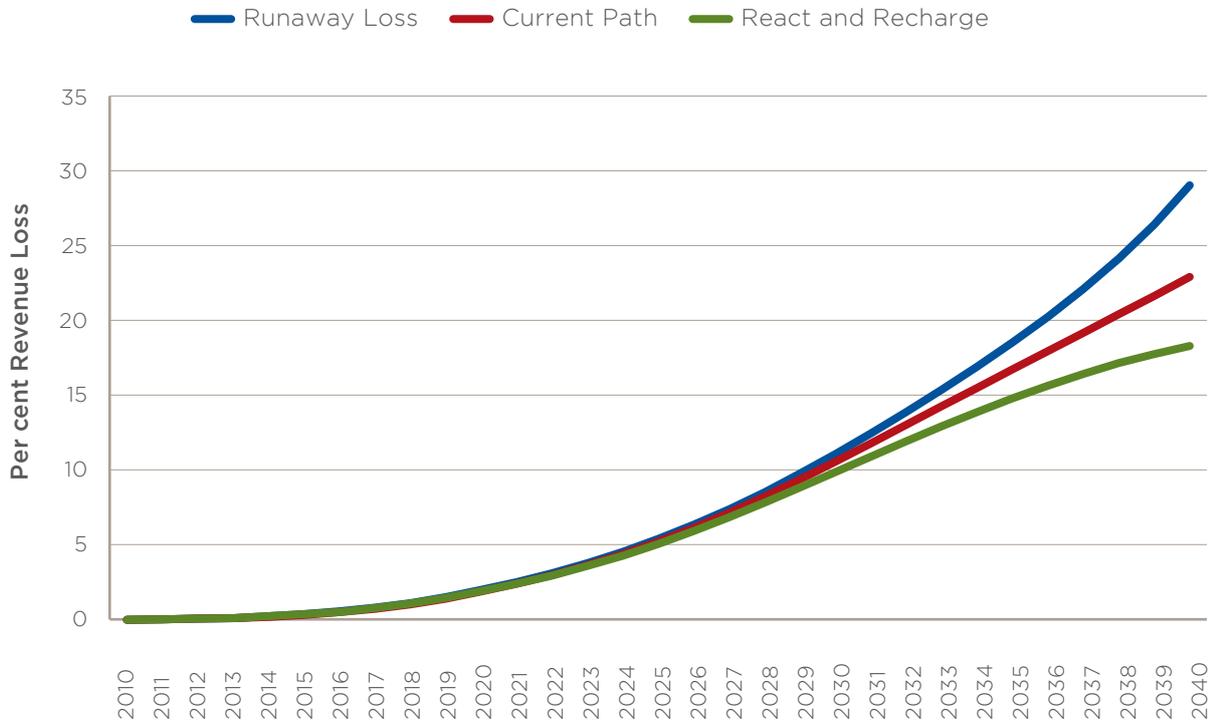
Source: International Futures (IFs) version 7.09 and authors' external model. See appendix A for description of IFs and appendix B for description of external model.

The revenue losses that occur in the Current Path scenario compared to the installation of AMI with different accompanying policies and investments in efficiency are identified in Figure 6. In React and Recharge initial losses are slightly greater than in the Current Path because of the costs of investment required for AMI. By 2016, however,^{62,63} a smart grid that uses different tariff rates for buying and selling electricity allows municipalities to reclaim lost revenue and by 2040 the smart grid significantly lowers revenue loss. In Figure 6 we see the component costs and benefits of investments in AMI in React and Recharge. Initial investments in AMI encourage further PV uptake, which increases revenue loss. Revenue reclaimed through FITs, however, offset this loss. There are small gains through cost reduction and economic growth as well. Our React and Recharge scenario still forecasts nearly R870 billion in cumulative revenue loss by 2040, but this is a 12% decrease compared to the R990 billion in the Current Path scenario.⁶⁴

To understand the delicate nature of smart meter implementation we have created a Runaway Loss scenario where the investments in smart meters and encouraging tariffs are not accompanied by investments in efficiency or responsive price mechanisms. This situation could result in a vicious feedback loop. While it is unlikely that this could occur in the real world – runaway losses would lead to a restructuring or abandonment of the tariff structure – but may be a stylized way of further unpacking this problem. Restructuring tariffs can mitigate these runaway losses, but without additional investments in smart technology and efficiency AMI implementation is likely to be worse than Current Path. Our React and Recharge scenario assumes no more than 25% transmission loss in excess

electricity produced through private PV and that the price of electricity bought from consumers be no more than 50% of the price for which it is sold⁶⁵. The City of Cape Town has pioneered the introduction of a Net FIT equivalent, the 'embedded generation' tariff, indicating that the problems of management are beginning to be dealt with in the Western Cape.⁶⁶

Figure 6: Revenue losses with AMI and Net FIT



Source: International Futures (IFs) version 7.09 and authors' external model. See appendix A for description of IFs and appendix B for description of external model.

The actual adoption rates of PV in the Western Cape will obviously most directly affect revenue losses. The study done on the Hessequa municipality, for example, saw very little revenue losses, driven by low forecasted levels of residential PV uptake. The reduction in capital-to-output ratios associated with an investment in AMI, however, is probably the single largest uncertainty and variable in the entire analysis to this point. The impact of AMI on the cost of producing energy is heavily dependent on the tariff structures put in place and the current efficiency of the grid. We have made assumptions based on the information available about how the PV trend is unfolding in the Western Cape, but without more extensive data it is difficult to create a more detailed picture.

While a more efficient grid is necessary to fully capitalise on any FITs, it is difficult to know the extent of investment required to achieve the high levels of efficiency necessary. However, AMI has many benefits other than simply facilitating FITs. Investments in AMI will not only lay the groundwork for the positive React and Recharge future but will also produce the data that analysts need to understand how the residential PV trend is progressing in the Western Cape. It is only with this data that the appropriate decisions, policies and investments can be made to facilitate a grid smart enough to truly capitalise on private PV and reach the critical mass necessary to enter the Embrace and Enhance scenario.

Embrace and enhance: Western Cape industry response to change

While revenue losses can be partially mitigated through the implementation of AMI and tariffs, these investments will not lead to an advanced smart grid with significant additional spillover effects. With enough investment and technology development in making the grid more intelligent, a critical mass can be reached that results in additional positive economic output in other sectors such as manufacturing and ICT. These additional economic gains can further offset revenue loss, although they are still not sufficiently large to fully make up all revenue losses from decentralised PV deployment.

The Embrace and Enhance scenario meets residential PV uptake with high levels of investment in AMI and grid efficiency, along with the development of a local PV manufacturing market. In this scenario the grid is smarter and more efficient at distributing electricity than in React and Recharge, allowing the province to make better use of excess energy produced by residential PV. In addition, a local PV manufacturing sector supplies many components of this domestic demand, although silicon cell production never comes online. Heavy investments in smart grid technology also lead to economic spillover benefits that stem from the ICT sector. Although initial investments mean even more revenue loss over the short term, these investments pay off and this scenario forecasts the lowest cumulative revenue losses of those explored in this brief.

A smarter grid allows for more efficient distribution of excess electricity produced by residential consumers and administration of FITs and ToU tariffs. Overall, almost 36 million barrels oil equivalent of residential PV is produced in Embrace and Enhance in 2040, a 44% increase over Current Path and a 9% increase over React and Recharge. While more investment is required to reach these levels of production, a more efficient grid means that less of this excess production is lost through transmission and distribution, and more electricity can be resold to consumers.

As in React and Recharge however, these tariffs encourage even more PV uptake, increasing revenue losses. These additional revenue losses are not insignificant – in 2040 they reduce by almost 50% all of the revenue reclaimed through the FIT.⁶⁷ To the extent that tariffs and efficiency make residential PV more competitive to consumers and as an energy source for the province, other fuel types become less competitive. This means less investment is required in other fuel types such as coal, but we find that this cost reduction is almost insignificant when compared to the other losses and gains in our forecast. All of these effects of a more efficient and smarter grid and the accompanying tariffs are factored into total revenue losses for this scenario.

Embrace and Enhance envisages a future where local PV manufacturing facilities in the Western Cape grow to meet rising demand, leading to economic benefits throughout the value chain. Although small relative to many international competitors, the South African solar industry manufactures solar panels, inverters, mounting hardware and other components of residential installation, and much of this activity is situated in the Western Cape. The Western Cape is home to all four South African PV module manufacturing facilities,^{68,69} and also hosts facilities that manufacture inverters for PV systems. The PV module and inverter are typically the most expensive parts of a PV installation, and while prices for South African-manufactured modules and inverters tend to be higher than the international average, they are broadly market-competitive.⁷⁰

However, in contrast to utility-scale producers under the REIPPP that are obliged to use South African labour and services for significant portions of their overall project costs, private PV buyers are not subject to localisation requirements. Small differences in price or quality are very likely to sway rooftop PV buyers' decisions away from South African products. In a study for the Department of Trade and Industry (DTI), interviews with South African industry role players confirm that many buyers choose imported products due to a variety of factors, with some reporting higher costs and/or lower quality in South African-manufactured PV modules.⁷¹ As the market evolves and matures, this perception may change, but in the short term it could significantly limit the amount of localised benefit the Western Cape sees from the growing solar industry.

To estimate added economic benefit to the Western Cape from a local PV industry, we used our PV uptake forecasts from our Current Path scenario and tied them to the declining cost per watt of PV installations and the percentage of that cost that will be spent within the province, i.e. the 'localisation factor'. We estimate that 36% of the cost of residential PV installations will be kept within the province by 2040, which relies on the assumption that many of the components will be built in the Western Cape, with the exception of silicon cells. We estimate that the cost per watt of residential PV will decrease logarithmically to below R14/W by 2040. Under these assumptions we find that the local residential PV industry can contribute a cumulative R217 billion to the Western Cape by 2040.

Finally, we considered how PV growth coupled with AMI can contribute to a more efficient, networked infrastructure system. Smart meters most commonly rely on fixed or mobile broadband networks for communication with utilities, and the capacity to run a smarter grid with efficient distribution of rooftop PV electricity will depend in part on municipal connection to quality communications networks. ICT is also known to have important spillover benefits in the wider economy, where it improves productivity and enhances high-tech growth.^{72,73}

While React and Recharge requires investments in ICT, Embrace and Enhance sees much larger investments.⁷⁴ Spillovers from ICT require that a critical mass of investment be reached, and while there are some benefits from the limited ICT requirements in React and Recharge, Embrace and Enhance requires large enough investments to see significant ICT spillover benefits.

In Figure 9 we see initial revenue losses of R990 billion along with the component costs and benefits associated with the Embrace and Enhance scenario. Smart grid investment is much higher in Embrace and Enhance than in React and Recharge due to larger investments in smart infrastructure and efficiency – R77 billion cumulatively compared to R8 billion in React and Recharge. This leads to even more additional PV uptake, which increases revenue loss but also allows excess electricity to be redistributed more effectively due to a more efficient grid, resulting in higher revenue reclaimed through FIT. Cost reduction and increases in government revenue due to GDP growth also help to mitigate revenue losses, and manufacturing value added in the PV sector significantly reduces revenue losses (See Appendix C – equitable shares for more information). Overall, the Western Cape only loses R588 billion cumulatively compared to the Current Path losses of R990 billion.

Figure 7 : Revenue loss in Embrace and Enhance

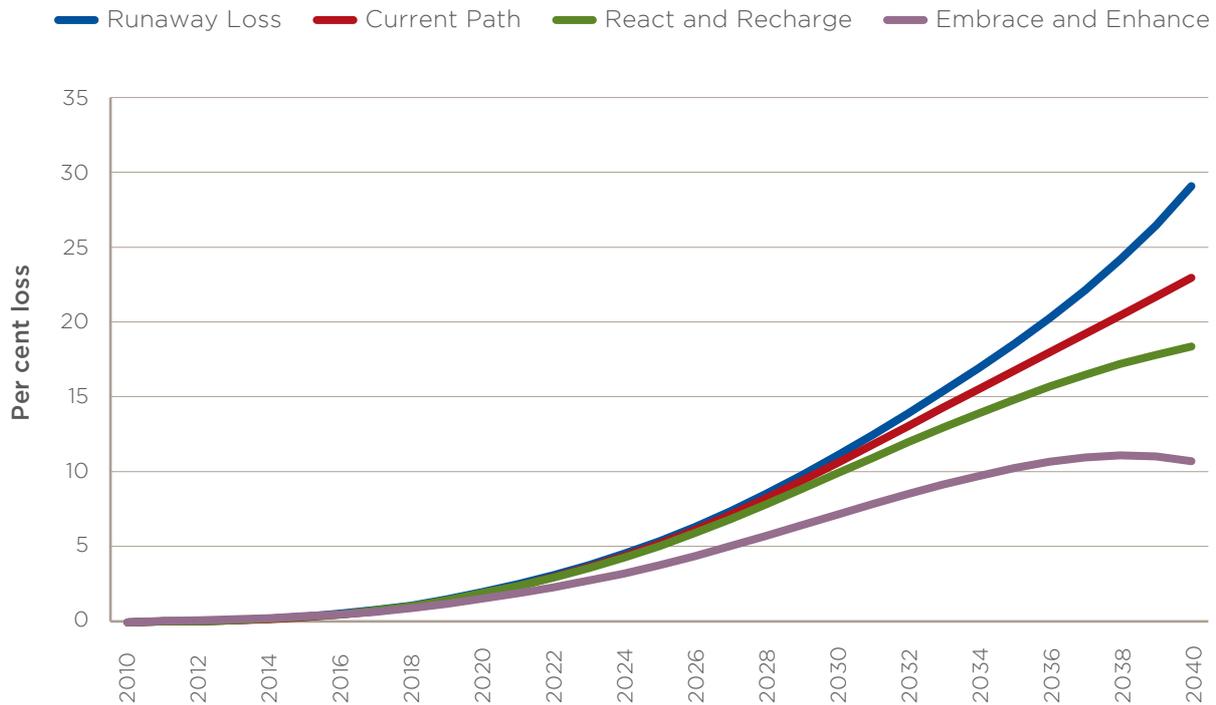


Note: Initial revenue loss of R990 billion from PV uptake displayed on the left in purple followed by the component costs (in red) and benefits (in green) of the Embrace and Enhance scenario. Overall revenue loss of R582 billion in the Embrace and Enhance scenario on the far right. All data in 2011 rand.

Source: International Futures (IFs) version 7.09 and authors’ external model. See appendix A for description of IFs and appendix B for description of external model.

We have included increases in ICT investments in the Embrace and Enhance scenario, which further increases total government revenue in the Western Cape. However, even with all of the increases in revenue from a more efficient grid and better redistribution of excess energy, and manufacturing and ICT spillovers, the Western Cape is still forecast to lose 6.5% of cumulative revenue from now to 2040 in Embrace and Enhance. In 2040, almost 11% of Western Cape revenue is lost due to residential PV, although the portion begins to decrease.

Figure 8 : Revenue loss in all scenarios (non-cumulative)



Source: International Futures (IFs) version 7.09 and authors' external model. See appendix A for description of IFs and appendix B for description of external model.

Embrace and Enhance tells a positive story of mutually reinforcing growth, in which policy adopted at the local level leads to a booming market for local PV industry across the province and the country as a whole. While revenue losses still occur due to residential PV in this scenario, the shape of the curve of revenue losses is different from the other scenarios. In contrast to Runaway Loss and Current Path, revenue losses in Embrace and Enhance begin to plateau by 2035 and even start to improve by 2040.

However, the projected gains in the PV industry are highly uncertain. If PV systems are slow to achieve cost-effectiveness in South Africa, if the quality of South African-manufactured PV products does not match the quality of imported goods, or if localisation potentials are not achieved due to lack of investment or too-high local labour and regulation costs, South African PV is likely to struggle.

Additionally, these gains cannot be unlocked without a commitment to updating the metering infrastructure and consumer incentives in the Western Cape, with these efforts matched at least to some level across the country to stimulate a robust domestic market. Embrace and Enhance contains many long-term gains that can only be achieved through short-term investments in AMI. And as with React and Recharge, without investments in AMI to gather data on domestic PV trends it will be difficult to know going forward how large the market for domestic PV industry truly is. Thus, while Embrace and Enhance sees the lowest levels of revenue loss, due to the uncertainty over these long-term economic gains and the contingency of these gains on AMI, it should not be seen as the current policy goal but rather as a long-term strategic possibility that might be possible depending on short- and medium-term policy choices listed previously.

Conclusions and recommendations

As presented in this policy brief, it is clear that an unfolding municipal revenue problem is developing in the Western Cape. This problem is driven by the decreasing cost of PV decentralised production that will cause high-end electricity consumers to buy less electricity directly from the grid. This will undermine municipal revenue generation and pro-poor spending policies.

There is no silver bullet that can overcome this problem. In every scenario we modelled we saw an overall loss of municipal revenue in the Western Cape. Since the proportion of revenue generated through electricity sales varies in different municipalities, it is likely that some will suffer worse than others. WCG agencies mandated to assist local government could be called on to help struggling municipalities adapt. Alternative paths must be identified to support municipal revenue generation that does not occur directly through electricity production and consumption. While the situation is challenging, it can also be seen as an opportunity. The province currently lacks reliable information on electricity consumption, a major barrier to accurate analysis and policy prescriptions. This should be remedied through an immediate investment in AMI. After this short-term investment, the Western Cape should explore deploying the FIT and ToU tariff structures identified in the React and Recharge scenario (which rely on AMI technology). Here, policymakers have to pay special attention to how tariffs are structured in order to avoid a Runaway Loss situation. It is very plausible that these tariffs will help municipalities capture some of the lost revenues.

Finally, and from a long-term strategic perspective, the Western Cape should look to developments in smart grid technology throughout the world to identify when it makes sense to invest heavily in a technologically demanding, highly smart grid infrastructure. That could, in the long run, lead to positive spillovers for government revenues, human development and the environment.

While this brief explores policy options it does not constitute official policy of the Western Cape Government.

Appendix A

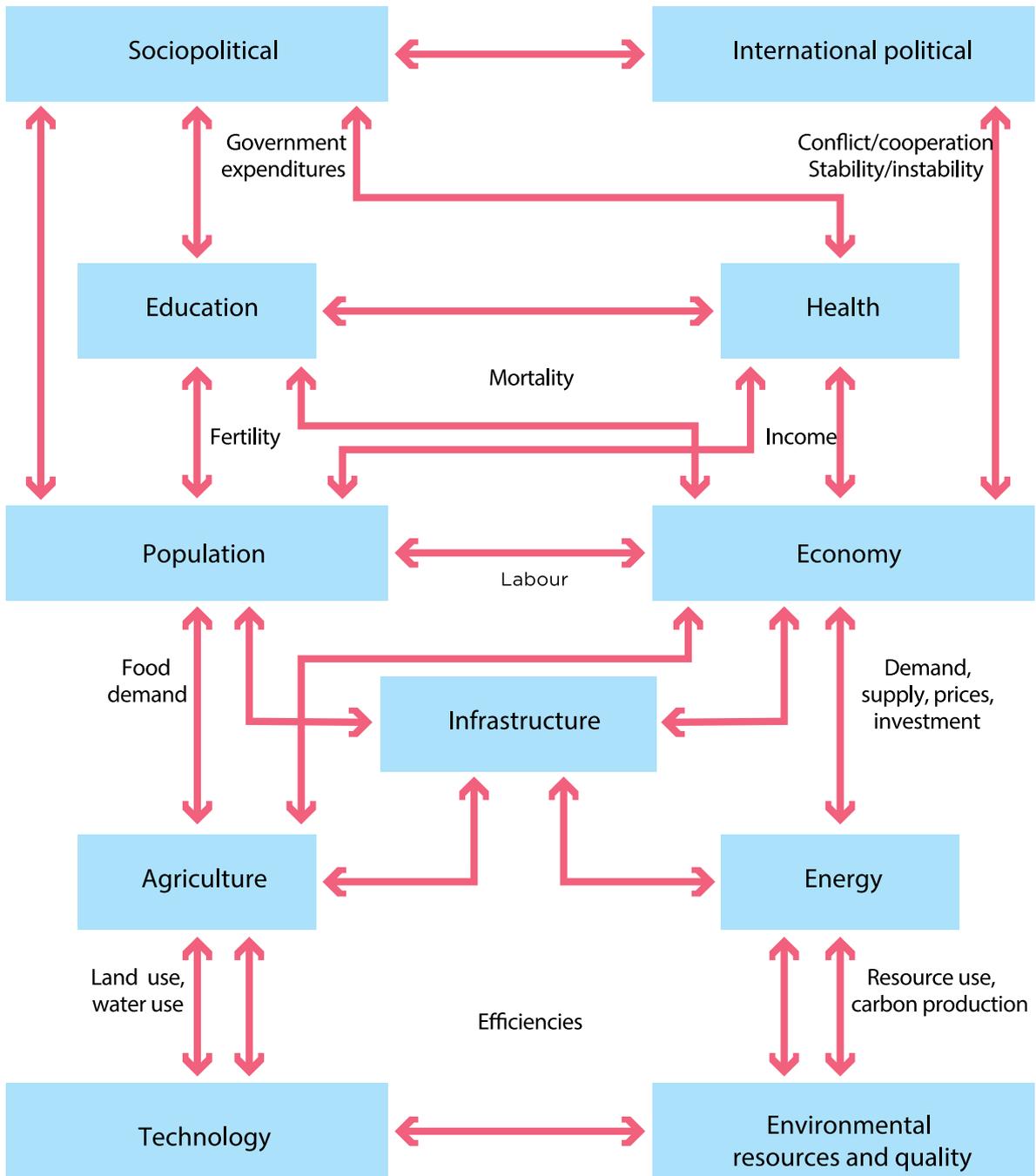
Understanding International Futures

The International Futures (IFs) tool models relationships across variables from a wide range of key global systems for 186 countries from 2010 to the end of the century. Relationships are structured in the model in two interconnected ways: firstly, by leveraging a very large set of historical data series from many renowned international data collection organisations (nearly 3 000 series in the most recent version of the model) and, secondly, by relying heavily on academic literature. IFs should not be thought of as purely a forecasting tool, but rather as a dynamic scenario-building tool that allows for the modelling of long-term futures concerning development across human, social and natural systems. It is important to think of IFs forecasts as highly contingent scenarios – not predictions.

IFs allows users to perform three types of analysis. Firstly, historical trends and relationships can be analysed to understand how a country has developed over time. Secondly, these relationships are formalised in the model to produce Base Case forecasts. These initial forecasts, which are integrated across all systems covered in IFs, are useful indicators of where a country seems to be heading under current circumstances and policies, and in the absence of major shocks to the system (wars, pandemics, etc.). Thirdly, scenario analyses augment the base case analysis by exploring the leverage that policymakers may have to push systems to more desirable outcomes.

The IFs base case is a collection of central tendency forecasts that represent a scenario of how the future may unfold. The base case assumes no major paradigm shifts, policy changes or ‘black swans’ (very low probability but high-impact events, such as a global pandemic or a nuclear war). Although the base case generally demonstrates continuity with historical patterns, it provides a structure that can also generate a wide range of non-linear, dynamic and endogenous forecasts rather than just a simple linear extrapolation of historical trends. Given that the base case is built from initial conditions of all historical variables and is periodically analysed and assessed in comparison to many other forecasts, it can be a good starting point to carry out scenario analysis and construct alternative future scenarios. Users can build their own alternative scenarios to the IFs base case or other forecasts by altering parameters within the system.⁷⁶

Figure 9 : Visual representation of the IFs structure



Links shown are examples from much larger set, and technology elements are dispersed throughout the modeling system.

Within the framework of collaboration with the Western Cape Government, the African Futures Project produces integrated forecasts for all nine provinces of South Africa. The Western Cape Government is taking the lead in utilising the model in its policy research and planning processes. IFs allows decision makers to assess policy impacts across key human, economic and natural systems, and shape reasonable expectations about long-term strategic planning initiatives aimed at promoting human development across the Western Cape.

The initial work for this project involved data gathering, cleaning and organisation at the provincial level. In doing so, we have incrementally constructed a database of major international indicators for policymakers and the academic community in the Western Cape. This database houses many different kinds of data under one roof, which allows users to analyse trends and understand change across a broad range of categories.⁷⁷

Appendix B

Modelling PV uptake and smart grid reclamation

Modelling PV uptake

We forecast different PV uptake rates for each group using the following sigmoid equation:⁷⁸

$$\text{Number of households with PV} = \text{Max Demand} * e^{(\text{take off year} * e^{-c * t})}$$

Forecasts of the total number of households connected to electricity out to 2040 were drawn from IFs. Access to electricity is a variable that is forecast within the infrastructure module of the IFs system. The forecast was then disaggregated into electricity connections within the City of Cape Town and in all other municipalities by using the portion of electrified households in Cape Town over the total number of electrified households in the Western Cape and keeping this proportion constant over time.

'Max PV access' is defined as the total number of households that have the possibility of installing PV. This varies as the number of connections increases. This parameter is almost entirely a function of income — high-income consumers are likely to consume more electricity and are charged at higher rates, and thus have more incentives to install cheaper PV. Max PV access is not entirely constrained by physical location either, and the forecast allows the possibility of consumers investing in community PV capacity that is not installed on their own homes but produces electricity for local consumption.

We estimate max PV access as a constant portion of total household connections. This parameter ranges from as high as 41% of potential households in the Cape Town Metro installing rooftop PV and as low as 31% of households in non-Cape Town local municipalities.⁷⁹ This relies on assumptions regarding income and electricity tariff structures. We use income groups drawn from the Census for the City of Cape Town and all other municipalities to determine the different max demand values.

Due to the nature of the sigmoid function, however, PV penetration never reaches these levels. 'Take off year' is the year at which the rate of adoption is the highest, c equals the rate of adoption, and t is the current year. Based on cost trends, we assume that the take-off year for rooftop solar is 2016 and that the rate of adoption varies from 10% for all municipalities other than Cape Town to 12% in Cape Town.⁸⁰ Under these assumptions we forecast that over 670 000 households will have PV systems by 2040.

Capacity and output assumptions

In order to calculate total PV capacity for each municipality we assume an average size of 6 kWp for each household PV installation.⁸¹ Additionally, we calculated total output in kWh by assuming a 20% efficiency rate (1 kWp = 1.775 kWh) for private PV, resulting in a capital-output ratio of \$88/barrel oil equivalent.^{82,83} We then assume that the capital-output ratio decreases at 1.5% per year over our time horizon.⁸⁴

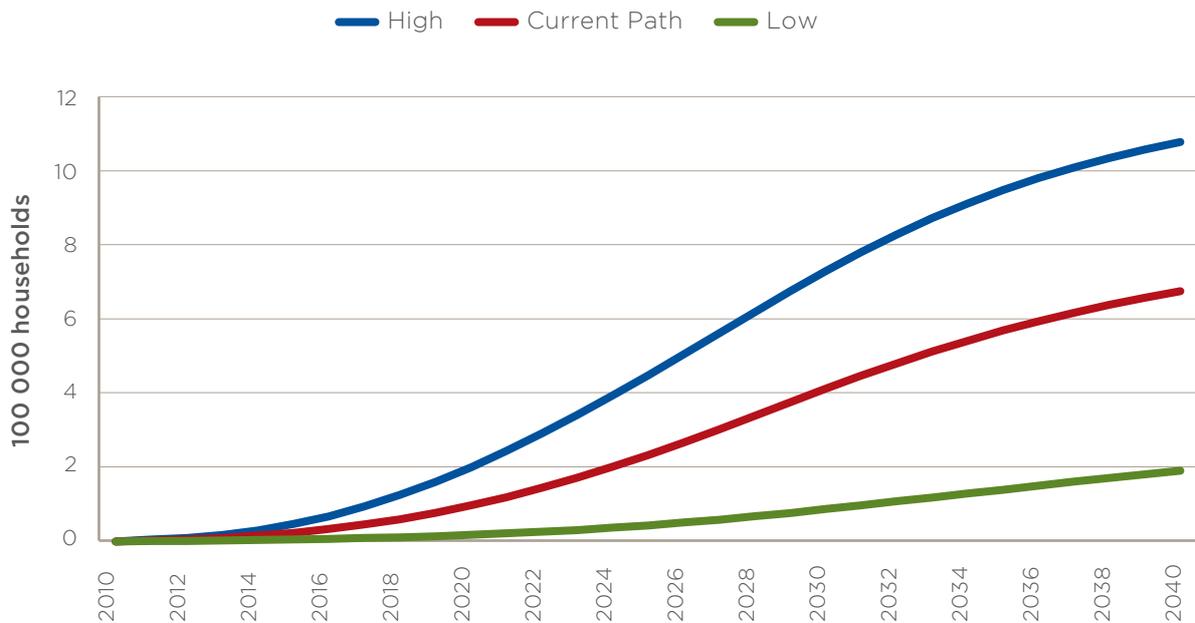
Our assumptions are relatively uniform for the municipalities, and it is inevitable that some municipalities will experience higher PV uptake than others due to local circumstances of climate or household types. Therefore these forecasts must be seen as a general estimate of the scope of the impact for the province rather than a specific forecast for municipalities. Our results also do not imply that all municipalities will suffer the same budget impact in the short or long term. Some municipalities depend on electricity revenue to a greater degree than others, and policies undertaken in response to the PV trend can also shift the balance.

To estimate the amount of revenue that is lost due to residential PV, we assume that any energy produced by residential PV would have been sold to consumers at the highest tariff for electricity. We forecast this tariff to increase over time.

Sensitivity analysis

Our PV uptake forecasts are highly sensitive to changes in max demand and adoption rates. We have created two alternative PV uptake forecasts. In the High PV uptake scenario, over 1 075 000 households install PV systems by 2040. In the Low scenario 185 000 households install PV systems.

Figure 10 : Highest and lowest assumptions of PV uptake vs. Current Path



Source: International Futures (IFs) version 7.09 and authors' external model. See appendix A for description of IFs and appendix B for description of external model.

React and recharge

We forecast the cost of AMI, including installation, to decrease logarithmically to below R3 000 per household by 2018 and then to below R1 000 by 2031. The cost of AMI investments is the product of this cost and the number of households that install residential PV systems in that year. We model the effects of these investments by decreasing the capital-output ratio (QE ratio) of renewable energy by 20% below Current Path values by 2040 within the IFs model. This relies on the assumption that investments in AMI will increase the efficiency of PV production. AMI will improve efficiency through decreased transmission losses and better information, but it will also allow electricity to be fed back into the grid from residential consumers. This increases the total amount of output produced by the same amount of capital.

IFs does not forecast PV separately from other renewable energy types and thus we use the 'Other renewable' category, which includes PV, solar thermal, wind energy, tidal, biodiesel, biogas and geothermal energy. Using IFs we are able to follow all of the forward linkages of a decrease in the cost of renewable energy. There are three consequences of this intervention that we include in our React and Recharge scenario. First, renewable energy production increases. Second, investment in renewable energy increases. Third, investment in other energy types decreases.

We use the increases in renewable energy production to estimate the levels of revenue that can be reclaimed through tariffs. The amount of revenue that can be reclaimed through tariffs is a function of the increase in production from our QE intervention, efficiency of the redistribution of this energy, and the tariff rate differential between the prices of electricity that the municipality buys from consumers and the price at which it is sold. We forecast the efficiency of redistribution to decrease over time as a function of the number of households that install PV. This relies on the

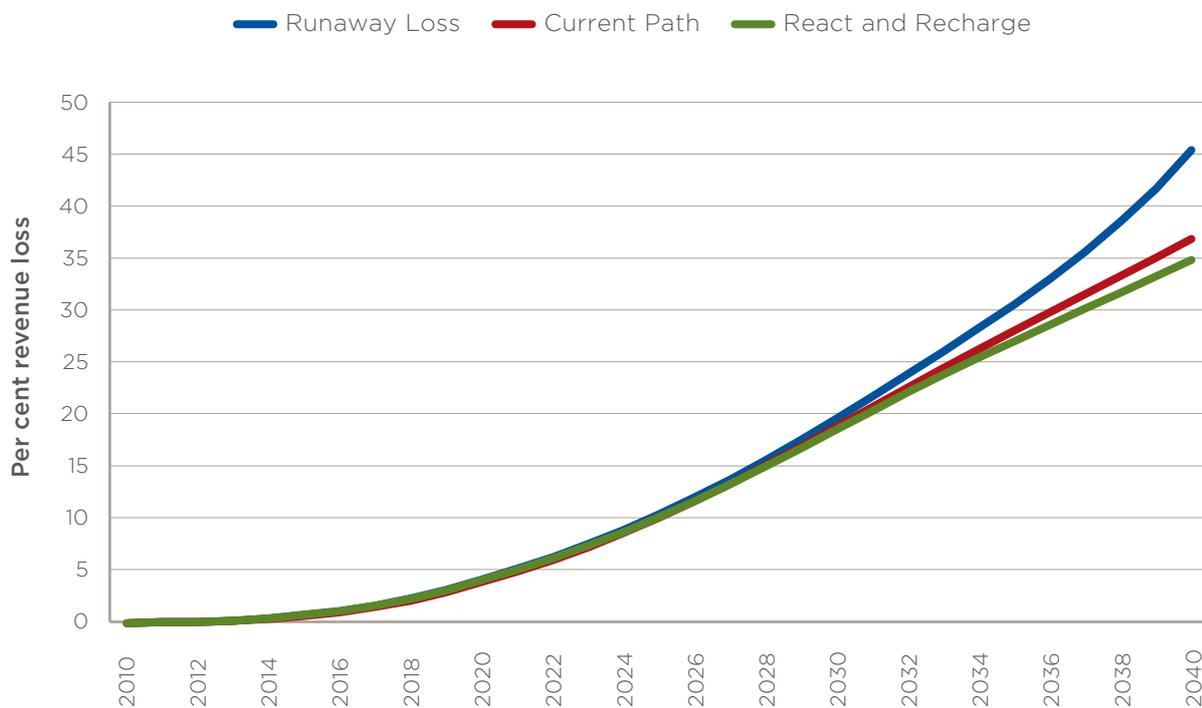
assumption that as production becomes more decentralised it becomes more difficult to efficiently redistribute the energy that is fed into the grid from FIT. We assume that the municipality is able to sell this excess production at the highest tariff rate and that this tariff rate increases over time in line with our projections for revenue loss. We also assume that the municipality buys electricity from residential PV consumers for 50% of the price at which it is sold. We forecast increased levels of investment in renewable energy using changes in capital of renewable energy in IFs compared to the Current Path. This investment is then translated into additional revenue loss by assuming that this additional capital represents additional grid defection and the associated loss of municipal revenues. Likewise, we forecast changes in investment levels in other fuel types by changes of capital.

Additionally, we increase access to fixed broadband by 5% over Current Path levels by 2040. This has many forward linkages, including an increase in government revenue as forecast within the IFs model (GOVREV). We add this additional gain in revenue to our net revenue reclaim calculation.

$$\begin{aligned}
 & \text{React and recharge revenue loss} \\
 & = \text{Revenue loss from PV uptake} \\
 & + \text{Additional revenue loss from increased PV investment} \\
 & + \text{Cost of AMI-Revenue reclaim through tariffs} \\
 & - \text{Cost reduction from other energy sources} \\
 & - \text{Change in government revenue within IFs (GOVREV)}
 \end{aligned}$$

Applying React and Recharge to different uptake rates

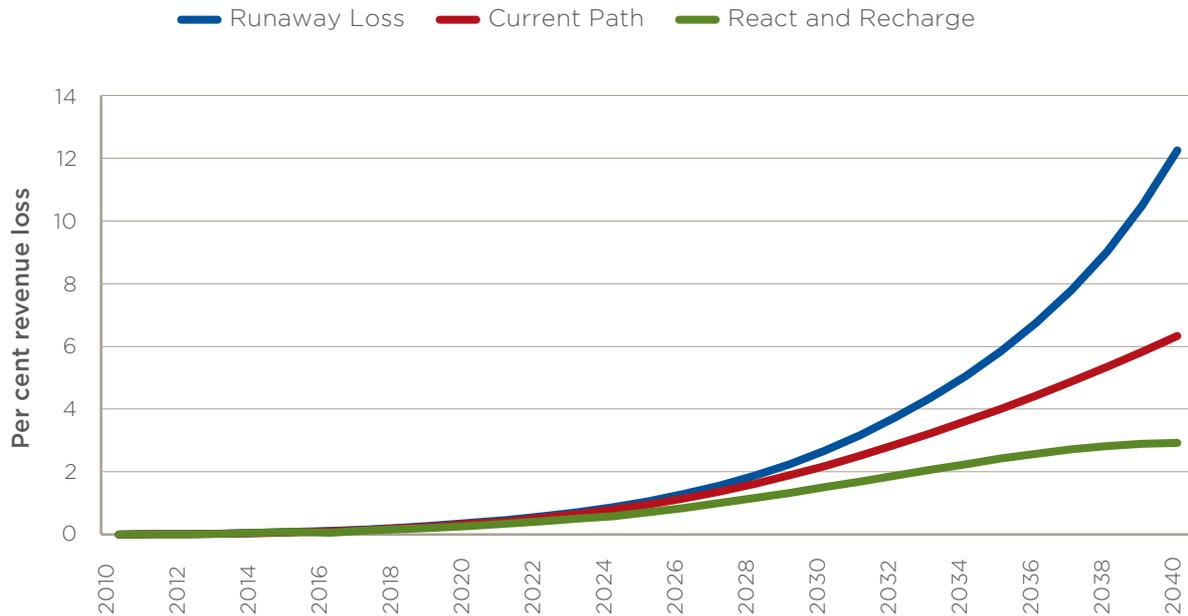
Figure 11 : Sensitivity analysis of revenue loss under high PV uptake assumptions



Source: International Futures (IFs) version 7.09 and authors' external model. See appendix A for description of IFs and appendix B for description of external model.

In our High PV Uptake scenario, revenue losses are considerably higher. The Current Path leads to over 36% revenue loss by 2040 (non-cumulative). Using the same assumptions and interventions as in the brief, we find that investment in AMI still decreases overall revenue losses, provided the excess energy produced is redistributed efficiently. Without efficient redistribution of excess electricity, the Runaway Loss scenario has revenue losses growing to over 45% by 2040 (non-cumulative). With a well-administered tariff and efficient redistribution of excess electricity, however, the React and Recharge scenario decreases revenue losses to 35% by 2040.

Figure 12: Sensitivity analysis of revenue loss under low PV uptake assumptions



Source: International Futures (IFs) version 7.09 and authors’ external model. See appendix A for description of IFs and appendix B for description of external model.

With low levels of PV uptake, the Western Cape is still forecast to lose 6.3% of revenue by 2040, or a cumulative 2.6%. With Runaway Loss this could reach over 12% (non-cumulative), but with the policy interventions explained in ‘react and recharge’ losses can be reduced to just 3% by 2040 or just 1.5% cumulatively.

While the authors believe that the PV uptake forecast outlined in the main section of the brief is the most plausible, this sensitivity analysis confirms our analysis and policy recommendations. Regardless of the levels of residential PV uptake, the policy recommendations explained in this brief will benefit the province.

Embrace and enhance

In Embrace and Enhance, we assume higher levels of investment in AMI and associated smart technologies. We also reduce the QE ratio even more than in React and Recharge. This leads to further increases in renewable energy production and even more additional PV uptake, as well as less investment in other energy sources. We also assume that the grid is more efficient at redistributing this excess energy and while efficiency still decreases as more consumers install PV, no more than 5% of the excess electricity fed into the grid from residential PV is lost.

In addition to the costs and benefits associated with smart grid investments explained in React and Recharge, Embrace and Enhance includes additional spillover benefits. We estimate that a portion of the cost of PV uptake will be spent within the province, increasing the manufacturing sector’s value added. We forecast the cost per watt of PV to decrease using the following equation (this equation closely matches estimates of cost per watt of PV found in ‘The localisation potential of photovoltaics’):²²

$$\text{Cost per Watt of PV} = -6.488 * \ln(\text{Current Year} - 2010) + 36.025$$

We then forecast the total cost of residential PV to 2040 using our PV uptake forecast. The portion of cost kept within the province, or the ‘localisation factor’, is assumed to be 36% by 2040. This is in line with the estimate in the low-road scenario in the ‘The localisation potential of photovoltaics’ paper. The low-road scenario assumes that many of the PV components are built in the Western Cape but that silicon cells are not.

Embrace and Enhance also contains higher levels of investment in ICT than does React and Recharge, which is forecast using parameters within the IFs model. These investments reduce revenue over the short term but have long-term gains, which we include in our calculations of revenue loss:

$$\begin{aligned} & \textit{Embrace and enhance revenue loss} \\ & = \textit{Revenue loss from PV uptake} \\ & + \textit{Additional revenue loss from increased PV investment} \\ & + \textit{Cost of smart grid investment} \\ & - \textit{Revenue reclaim through tariffs} \\ & - \textit{Cost reduction from other energy sources} \\ & - \textit{Manufacturing value added-Change in government revenue within IFs} \\ & \quad \textit{(GOVREV)} \end{aligned}$$

Appendix C

Equitable shares

In the Embrace and Enhance scenario, investment in AMI in the Western Cape not only mitigates a significant portion of projected revenue losses from residential PV but also projects that the amounts being added to Western Cape GDP from residential PV and associated industry could decrease losses from electricity tariffs, more so than in either the Current Path scenario or React and Recharge. On paper, this should justify the investment. However, for the Western Cape Government, higher economic growth does not necessarily result in higher budget returns. The structure of the equitable shares formula - through which provincial shares of the national budget are determined - means that a relatively small amount of the tax revenue boosts from increased GDP will accrue back to the Western Cape.

Given these realities, it is unlikely that provincial investments in AMI could be recovered purely through tax revenue accruing to the Western Cape alone. Investment should instead be understood as a developmental expenditure, necessary to understand and secure the electricity supply and provide municipalities with the tools they need to respond.

Notes

1. The previous policy briefs have focused on the Educating Cape and the Enterprising Cape transitions.
2. Can be retrieved from: https://www.capetown.gov.za/en/IDP/Documents/OneCape_2040.pdf
3. More detail is provided in Appendix A.
4. Andrew Marquard et al, South Africa's electrification program: an overview and assessment, University of Cape Town, working paper, December 2007, <http://www.gsb.uct.ac.za/files/SAElectrificationworkingpaperfinal.pdf> (accessed 24 October 2014).
5. Statistics South Africa, Electricity generated and available for distribution, September 2014, <http://beta2.statssa.gov.za/publications/P4141/P4141September2014.pdf> (accessed 1 December 2014).
6. Department of Energy, Integrated Resource Plan for Electricity (IRP) 2010-2030: Update Report 2013, 21 November 2013, <http://www.doe-irp.co.za/> (accessed 15 October 2014).
7. The South African state-run electricity provider.
8. Deloitte, The economic impact of electricity price increases on various sectors of the South African economy: a consolidated view based on the findings of existing research, http://www.eskom.co.za/CustomerCare/MYPD3/Documents/Economic_Impact_of_Electricity_Price_Increases_Document1.pdf (accessed 5 December 2014).
9. City of Cape Town, Cape Town 2011: state of energy and energy futures report, http://www.capetown.gov.za/en/EnvironmentalResourceManagement/publications/Documents/State_of_Energy+_Energy_Futures_Report_2011_revised_2012-01.pdf (accessed 30 October 2014).
10. National Energy Regulator of South Africa (NERSA), Multi-year price determination 2013/2014 to 2017/2018, <http://www.eskom.co.za/CustomerCare/MYPD3/Documents/NersaReasonsforDecision.pdf> (accessed 30 October 2014).
11. See Lindsay Wilson, Average electricity prices around the world: \$/kWh, Shrink that footprint, <http://shrinkthatfootprint.com/average-electricity-prices-kwh> (accessed 30 October 2014).
12. Carol Paton, Bid to cap Eskom tariff rise, Business Day Live, 4 September 2014, <http://www.bdlive.co.za/business/energy/2014/09/04/bid-to-cap-eskom-tariff-rise> (accessed 4 December 2014).
13. Anton Eberhard, Realise that Eskom alone cannot solve our power crisis, Business Day Live, 26 November 2014, <http://www.bdlive.co.za/opinion/columnists/2014/11/26/realise-that-eskom-alone-cannot-solve-our-power-crisis> (accessed 26 November 2014).
14. Figures on Western Cape electricity consumption were provided by the Western Cape Government Department of Environmental Affairs and Development Planning.
15. Emissions Database for Global Atmospheric Research, Trends in global CO2 emissions, PBL Netherlands Environmental Assessment Agency, Report, 2013, http://edgar.jrc.ec.europa.eu/news_docs/pbl-2013-trends-in-global-co2-emissions-2013-report-1148.pdf (accessed 22 October 2014).
16. City of Cape Town, 2011: State of energy and energy futures report, http://www.capetown.gov.za/en/EnvironmentalResourceManagement/publications/Documents/State_of_Energy+_Energy_Futures_Report_2011_revised_2012-01.pdf (accessed 30 October 2014).
17. Western Cape Economic Development Partnership (EDP) for the Western Cape Government and the City of Cape Town, One Cape 2040: from vision to action, 19 October 2012, https://www.capetown.gov.za/en/IDP/Documents/OneCape_2040.pdf (accessed 24 October 2014).
18. Western Cape Department of Environmental Affairs and Development Planning, State of the environment outlook report for the Western Cape Province, September 2013, http://eadp-westerncape.kznsshf.gov.za/sites/default/files/your-resource-library/WCSO_EOR_08_Energy.pdf (accessed 22 October 2014).
19. The LCOE is the average cost of generating a unit of electricity over the lifetime of a particular technology, with all capital, operations, tax and fuel expenditures on that technology taken into account.
20. International Renewable Energy Agency, Solar photovoltaics, Renewable Energy Technologies: Cost Analysis Series, 1: 4/5, June 2012, http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-SOLAR_PV.pdf (accessed 15 October 2014).
21. Mike Rycroft, Andreas Wagenaar and Barbara Sabbione, Rooftop solar PV, an awakening giant, Energize, Jan/ Feb 2012, <http://www.sapvia.co.za/wp-content/uploads/2012/06/Sustainable-Energy-Rooftop-Solar-PV.pdf> (accessed 17 October 2014).
22. EScience Associates, Urban-Econ Development Economists and Chris Ahlfeldt, Photovoltaic electricity: the localisation potential of photovoltaics and a strategy to support large scale roll-out in South Africa, prepared for the South African Photovoltaic Industry Association, the World Wildlife Fund and the Department of Trade and Industry, March 2013, http://awsassets.wwf.org.za/downloads/the_localisation_potential_of_pv_and_a_strategy_to_support_large_scale_roll_out_in_sa.pdf (accessed 17 October 2014).
23. International Renewable Energy Agency, Solar photovoltaics, Renewable Energy Technologies: Cost Analysis Series, 1:4/5, June 2012, http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_

- Analysis-SOLAR_PV.pdf (accessed 15 October 2014).
24. European Photovoltaic Industry Association, Global market outlook for photovoltaics 2014-2018, http://www.epia.org/fileadmin/user_upload/Publications/EPIA_Global_Market_Outlook_for_Photovoltaics_2014-2018_-_Medium_Res.pdf (accessed 23 October 2014).
 25. Department of Energy, Integrated Resource Plan for Electricity (IRP) 2010-2030: Update Report 2013, 21 November 2013, <http://www.doe-irp.co.za/> (accessed 15 October 2014).
 26. EScience Associates, Urban-Econ Development Economists and Chris Ahlfeldt, Photovoltaic electricity: the localisation potential of photovoltaics and a strategy to support large scale roll-out in South Africa, prepared for the South African Photovoltaic Industry Association, the World Wildlife Fund and the Department of Trade and Industry, March 2013, http://awsassets.wwf.org.za/downloads/the_localisation_potential_of_pv_and_a_strategy_to_support_large_scale_roll_out_in_sa.pdf (accessed 17 October 2014).
 27. Ibid.
 28. Department of Energy, Integrated Resource Plan for Electricity (IRP) 2010-2030: Update Report 2013, 21 November 2013, <http://www.doe-irp.co.za/> (accessed 15 October 2014).
 29. Rocky Mountain Institute, Cohn Reznick and Homer Energy, The economics of grid defection: when and where distributed solar generation plus storage competes with traditional utility service, February 2014, www.rmi.org (accessed 1 December 2014).
 30. Roger Lilly, Understanding the new municipal electricity price increase, Energize, May 2013, http://www.ee.co.za/wp-content/uploads/legacy/Energize_2013/03_idn_roger-understanding.pdf (accessed 26 November 2014).
 31. A Janisch, M Euston-Brown and M Borchers, Death spirals and double whammies: the potential impact of efficiency measures and distributed generation on municipal electricity revenue, Sustainable Energy Africa, September 2012.
 32. Chelsea Geach, Cost of saving electricity, Cape Argus, 19 August 2014.
 33. Dirk de Vos, Analysis: how Telkom is the analogue of Eskom, Daily Maverick, 27 November 2014, <http://www.dailymaverick.co.za/article/2014-11-27-analysis-how-telkom-is-the-analogue-of-eskom/> (accessed 27 November 2014).
 34. A Janisch, M Euston-Brown and M Borchers, Death spirals and double whammies: the potential impact of efficiency measures and distributed generation on municipal electricity revenue, Sustainable Energy Africa, September 2012.
 35. Hilton Trollip et al, Potential impact on municipal revenue of small scale own generation and energy efficiency, paper submitted to the South African Economic Regulators Conference, 21-22 August 2012.
 36. Smart Grid Project Team and Green Cape Sector Development Agency, Towards a smart grid for the Witzenberg Municipality, 31 March 2014, <http://green-cape.co.za/smartgrids/docs/D5.pdf> (accessed 23 October 2014).
 37. Josh Reinecke et al, Unlocking the rooftop PV market in South Africa, Centre for Renewable and Sustainable Energy Studies, March 2013, http://www.crses.sun.ac.za/files/research/publications/technical-reports/Unlocking%20the%20Rooftop%20PV%20Market%20in%20SA_final.pdf (accessed 20 October 2014).
 38. While it is unlikely that no residential PV uptake occurs, this base case is necessary as a way to measure relative revenue losses.
 39. We set up a sensitivity analysis of this difference by allowing the max PV variable of the other municipalities to vary according to the low and high bounds set by the studies (see appendix B).
 40. Access to electricity is a variable that is forecast within the infrastructure module of the IFs forecasting system (for more information see annex).
 41. It is estimated that only 7.5% of households are eligible to install rooftop PV: see Josh Reinecke et al, Unlocking the rooftop PV market in South Africa, Centre for Renewable and Sustainable Energy Studies, March 2013, http://www.crses.sun.ac.za/files/research/publications/technical-reports/Unlocking%20the%20Rooftop%20PV%20Market%20in%20SA_final.pdf (accessed 20 October 2014). We have generalised this assumption as the low boundary of the sensitivity analysis.
 42. A 12% uptake rate in Cape Town and 10% elsewhere, weighted by household electricity connections.
 43. We allow for the possibility of consumers investing in private PV without installing directly on their roofs or property. This can be facilitated by community PV projects or alternative PV investment schemes.
 44. See NERSA, Potential impact on municipal revenue of small-scale own generation and energy efficiency July 2012.. This paper presents current VAT as well as forecasted increases in VAT for IBR 4.
 45. Harry Wirth, Recent facts about photovoltaics in Germany, Fraunhofer ISE, 16 October 2014, <http://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/recent-facts-about-photovoltaics-in-germany.pdf> (accessed 10 December 2014).
 46. M Pipattanasomporn, H Feroze and S Rahman, Multi-agent systems in a distributed smart grid: design and implementation, Power Systems Conference and Exposition, 2009, http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=4840087&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxppls%2Fabs_all.jsp%3Farnumber%3D4840087 (accessed 20 October 2014).
 47. Better information regarding electricity distribution or the lack thereof allows for faster and more appropriate

responses to attacks in the system or blackouts from natural causes. These responses can often be automated so that the system is able to respond automatically or “self heal” when disrupted.

48. V Gordiano et al, Smart grids projects in Europe: lessons learned and current developments, 2012 update, JRC Scientific and Policy Reports, 2013, http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/Id-na-25815-en-n_final_online_version_april_15_smart_grid_projects_in_europe_-_lessons_learned_and_current_developments_-2012_update.pdf (accessed 17 October 2014).
49. M Wolsink, The research agenda on social acceptance of distributed generation in smart grids: renewable as common pool resources, *Renewable and Sustainable Energy Reviews*, 16, 2012, 822-835.
50. MA Brown and S Zhou, Smart-grid policies: an international review, *WIREs Energy Environ*, 2, 2013, 121-139.
51. Ibid.
52. Ibid.
53. Smart Grid Project Team and Green Cape Sector Development Agency, Towards a smart grid for the Witzenberg Municipality, 31 March 2014, <http://green-cape.co.za/smartgrids/docs/D5.pdf> (accessed 23 October 2014).
54. For a detailed explanation of the energy module and to view the equations, see University of Denver, International Futures at the Pardee Center, du.edu/ifs/help/understand/energy/index.html.
55. IFs forecasts energy production from renewable energy as a sum of solar PV, solar thermal, wind energy, tidal, biodiesel, biogas and geothermal energy. Hydro power is forecast separately, but solar PV is not forecast in isolation.
56. The establishment of standards for smart meters is expected to help local manufacturers produce at scale and lower average prices dramatically. For a comprehensive review of smart meter technology and standards in South Africa, see Green Cape Sector Development Agency, Smart meters: technology review and role in the Western Cape 2013-2014, March 2014.
57. 2013 rand.
58. The net FIT and the income received by consumers from this will help fund the initial cost of capital of the PV system. Thus, the capital-output ratio for PV would decrease as the capital portion of the ratio decreases. Further, since electricity is being fed into the grid, less electricity is being wasted, resulting in an increase in the denominator of the capital-output ratio.
59. In 2013 the Fraunhofer Institute for Solar Energy Systems assessed recent trends in the German PV industry, and forecast that the LCOE for PV in Germany would decline at a pace that comfortably exceeds the rate we have set for the ‘react and recharge’ scenario.
60. For a full description of the future of the water sector in South Africa and the accompanying water sub-module of IFs, see S Hedden and J Cilliers, Parched prospects: the emerging water crisis in South Africa, Institute for Security Studies, September 2014, <http://www.issafrica.org/parched-prospects-the-emerging-water-crisis-in-south-africa> (accessed 1 December 2014)).
61. All rand amounts are set to 2011 values unless otherwise noted.
62. Forecasts of initial investments rely heavily on a dramatic decrease in the cost of smart meters.
63. Due to data constraints, the authors begin their forecast in 2011.
64. We estimate R9.1 trillion revenue cumulatively in the base case forecast of IFs.
65. While 25 per cent transmission and distribution losses may seem high we estimate higher losses due to the decentralized and intermittent nature of this electricity output. National transmission and distribution losses for South Africa were only 8 per cent in 2011, World DataBank < <http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS>>
66. Kristy Jooste, Cape Town to offset small-scale generation, Cape Business News, 21 August 2014, <http://www.cbn.co.za/services/power-solutions-energy-efficiency/item/2110-cape-town-to-off-set-small-scale-electricity-generation> (accessed 1 December 2014).
67. The relationship between additional revenue losses due to incentivised PV uptake and revenues reclaimed through FIT is complicated and the figures are not truly directly comparable. Additional PV uptake contributes to both additional revenue losses and additional revenue reclaim.
68. IOL News, Cape factory spurs green revolution, 6 August 2014, <http://www.iol.co.za/scitech/science/environment/cape-factory-spurs-green-revolution-1.1731439#.VEUCDGeSzaE> (accessed 20 October 2014).
69. EScience Associates, Urban-Econ Development Economists and Chris Ahlfeldt, The localisation potential of photovoltaics (PV) and a strategy to support large scale roll-out in South Africa, prepared for the South African Photovoltaic Industry Association, the World Wildlife Fund and the Department of Trade and Industry, March 2013, http://awsassets.wwf.org.za/downloads/the_localisation_potential_of_pv_and_a_strategy_to_support_large_scale_roll_out_in_sa.pdf (accessed 17 October 2014).
70. Ibid.
71. Ibid.
72. Andrea Bassanini and Stefano Scarpetta, Growth, technological change, and ICT diffusion: recent evidence from OECD countries, *Oxf Rev Econ Policy*, 18:3, 2002, 324-344.
73. Jonathan D Moyer and Barry B Hughes, ICTs: do they contribute to increased carbon emissions?, *Technological*

Forecasting & Social Change, 79, 2012, 919–931, <http://www.sciencedirect.com/science/article/pii/S0040162511002836> (accessed 5 December 2014).

74. The authors estimate that investment in AMI and smart infrastructure in 'embrace and enhance' will cost R14 203 in 2015 per unit of residential PV – over 3.5 times higher than in 'react and recharge'.
75. Barry B Hughes et al, Exploring future impacts of environmental constraints on human development, Sustainability, 2012, 958-994.
76. For further information on scenario analysis in IFs see the IFs Help System, <http://www.du.edu/ifs/help>.
77. For a case demonstrating the importance of relational databases in education, see Philip A Streifer, Using data to make better educational decisions, Lanham: Scarecrow Press, 2002.
78. Equation taken from EScience Associates, Urban-Econ Development Economists and Chris Ahlfeldt, The localisation potential of photovoltaics (PV) and a strategy to support large scale roll-out in South Africa, prepared for the South African Photovoltaic Industry Association, the World Wildlife Fund and the Department of Trade and Industry, March 2013, http://awsassets.wwf.org.za/downloads/the_localisation_potential_of_pv_and_a_strategy_to_support_large_scale_roll_out_in_sa.pdf (accessed 17 October 2014).
79. The Centre for Renewable and Sustainable Energy Studies estimates that only 7.5% of households are eligible to install rooftop PV: see Josh Reinecke et al, Unlocking the rooftop PV market in South Africa, Centre for Renewable and Sustainable Energy Studies, March 2013, http://www.crses.sun.ac.za/files/research/publications/technical-reports/Unlocking%20the%20Rooftop%20PV%20Market%20in%20SA_final.pdf (accessed 20 October 2014). We have generalised this assumption as the low boundary of the sensitivity analysis.
80. This is in line with other estimates for adoption rates. EScience Associates, Urban-Econ Development Economists and Chris Ahlfeldt, Photovoltaic electricity: the localisation potential of photovoltaics and a strategy to support large scale roll-out in South Africa, prepared for the South African Photovoltaic Industry Association, the World Wildlife Fund and the Department of Trade and Industry, March 2013, has three uptake scenarios: 10%, 7% and 5% adoption rates. We assume higher adoption rates for Cape Town based on NERSA, Potential impact on municipal revenue of small-scale own generation and energy efficiency, July 2012. It expects own-generation PV to grow to 100 000 households by 2021. We have incorporated this into our assumption of PV uptake in Cape Town by assuming a 12% adoption rate in Cape Town.
81. An analysis by Eskom PV analyst Dr Tobias Bischof-Niemz assumed a 6 kWp average size of installation. The South African IRP (2010–2030) assumes a 5 kWp average installation (Department of Energy, Integrated Resource Plan for Electricity [IRP] 2010–2030: Update Report 2013, 21 November 2013, 33). NERSA has scenarios for 8, 10 and 12 kWp installations: see NERSA, Potential impact on municipal revenue of small-scale own generation and energy efficiency, July 2012.
82. From a presentation given by Dr Tobias Bischof-Niemz.
83. Capital-output ratio (QE ratio) must be in US\$ per barrel oil equivalent for input in the International Futures model.
84. This is in line with the decrease in QE ratios built into the IFs model.

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www.issafrica.org/futures

Authors

Hanna Camp
Steve Hedden
David Bohl
Aa-ishah Petersen
Jonathan D Moyer

Series Editors

Jonathan D. Moyer
Julia Schünemann

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